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Occupation and the risk of adult glioma in the United States

A.J. De Roos[1,*], P.A. Stewart[1], M.S. Linet[1], E.F. Heineman[2], M. Dosemeci[1], T. Wilcosky[3], W.R. Shapiro[4], R.G. Selker[5], H.A. Fine[6], P.M. Black[7] & P.D. Inskip[1]

[1]*Division of Cancer Epidemiology and Genetics, National Cancer Institute, Bethesda, MD, USA;* [2]*Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, MD, USA;* [3]*Research Triangle Institute, Research Triangle Park, NC, USA;* [4]*Barrow Neurological Institute, St Joseph's Hospital and Medical Center, Phoenix, AZ, USA;* [5]*Western Pennsylvania Hospital, Pittsburgh, PA, USA;* [6]*Neuro-oncology Branch, National Cancer Institute, Bethesda, MD, USA;* [7]*Brigham and Women's Hospital, Boston, MA, USA (*Author for correspondence)*

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Abstract

Objective: Previous studies have observed increased glioma incidence associated with employment in the petroleum and electrical industries, and in farming. Several other occupations have also been associated with increased risk, but with inconsistent results. We evaluated associations between occupational title and glioma incidence in adults.
Methods: Cases were 489 patients with glioma diagnosed from 1994 to 1998 at three United States hospitals. Controls were 799 patients admitted to the same hospitals for non-malignant conditions. An experienced industrial hygienist grouped occupations that were expected to have similar tasks and exposures. The risk of adult glioma was evaluated for those subjects who ever worked in an occupational group for at least six months, those who worked longer than five years in the occupation, and those with more than ten years latency since starting work in the occupation.
Results: Several occupational groups were associated with increased glioma incidence for having ever worked in the occupation, including butchers and meat cutters (odds ratio [OR] = 2.4; 95% confidence limits [CL]: 1.0, 6.0), computer programmers and analysts (OR = 2.0; 95% CL: 1.0, 3.8), electricians (OR = 1.8; 95% CL: 0.8, 4.1), general farmers and farmworkers (OR = 2.5; 95% CL: 1.4, 4.7), inspectors, checkers, examiners, graders, and testers (OR = 1.5; 95% CL: 0.8, 2.7), investigators, examiners, adjustors, and appraisers (OR = 1.7; 95% CL: 0.8, 3.7), physicians and physician assistants (OR = 2.4; 95% CL: 0.8, 7.2), and store managers (OR = 1.6; 95% CL: 0.8, 3.1), whereas occupation as a childcare worker was associated with decreased glioma incidence (OR = 0.4; 95% CL: 0.2, 0.9). These associations generally persisted when the subjects worked longer than five years in the occupation, and for those with more than ten years latency since starting to work in the occupation.
Conclusions: This is our first analysis of occupation and will guide future exposure-specific assessments.

Introduction

Some of the stronger leads concerning potential causes of glioma have come from studies of occupation. Scientists have conducted both industry-based studies of specific occupations with suspected higher risks, and population-based case–control studies representing a broad spectrum of occupations. The bulk of studies indicated increased risk associated with employment in the petroleum industry, electricity-related jobs, and farming [1]. Studies of occupation have also provided clues concerning possible causal exposures, including solvents, electric and magnetic fields (EMF), and pesticides [1]. Although these findings do not usually translate into large population-attributable risks, they are important for the purpose of minimizing risks to workers' health, and may also give clues regarding potential environmental risk factors.

Because there have been some inconsistencies among study results, there is still a need for clarification and investigation in different study populations. Further information on associations of job-specific tasks and

work practices with glioma would be useful for assessing risk for jobs with considerable heterogeneity in the work environment. At the time we launched our large, hospital-based case–control study of adult brain tumors in the United States, there was a growing number of leads from the occupational literature, and this was one of the major areas we pursued [2]. An industrial hygienist was integrally involved in the design and data-collection phases of the study. In this initial examination of occupation, we evaluated occupational title and certain job-specific tasks and work practices as risk factors for glioma.

Materials and methods

Study population

Eligible cases were patients newly diagnosed with glioma (ICD-O-2 morphology codes 9380–9473) or other neuroepithelial neoplasms (ICD-O-2 codes 9490–9506) [3], hereafter collectively referred to as "glioma", from 1994 to 1998, age 18 years or older, who were treated at one of three participating United States hospitals located in Phoenix, AZ; Boston, MA; and Pittsburgh, PA. Eligible cases (or their next-of-kin) were approached after permission had been obtained from the treating physician to contact the case patient. The study objectives and procedures were then described and informed consent sought from the case patient or next-of-kin. We enrolled 489 glioma cases (among a total of 782 cases in the full study with eligible forms of malignant or benign brain tumors including glioma, meningioma, or acoustic neuroma), representing 92% of eligible glioma patients contacted. All glioma case diagnoses were histologically confirmed.

Control subjects were patients admitted to the same hospitals and treated for a variety of non-neoplastic conditions. Controls were frequency-matched to the total case series on hospital, age, sex, race, and proximity of residence to the hospital. A total of 799 control subjects was recruited, representing 86% of those eligible patients contacted. Major categories of discharge diagnoses of the control subjects were trauma, injury, or poisoning (24.7%), circulatory disease (22.4%), musculoskeletal disease (21.5%), digestive system disease (11.5%), and other diseases (19.9%).

A structured, standardized computerized questionnaire was administered in person by trained nurses, either directly with the subject or with a proxy for deceased or incapacitated subjects (proxy interviews were conducted for 16% of glioma cases and for 3% of control subjects). The occupational history section of the questionnaire collected detailed information on each job held for six months or longer since age 16, with the name and location of the employer, type of product or service provided, job title, year started and stopped working, full- or part-time status, and primary job activities or duties. In addition, for 64 occupations of *a-priori* interest, job-specific modules developed by an industrial hygienist were administered to elicit in-depth information on tasks, exposures, and other exposure-related variables for jobs held two years or longer [4, 5]. Data from the job modules are currently being evaluated to assess specific occupational exposures. Selected information on job-specific tasks and work practices from the modules are included in the present analysis.

Occupational coding

All coding of occupation was done without knowledge of case or control status, or gender. Occupations and industries were coded using the 1980 Standard Occupational Classification (SOC) and the 1987 Standard Industrial Classification (SIC) schemes [6, 7]. Occupations were then categorized by an experienced industrial hygienist (P.A.S.) and an epidemiologist (A.J.D.) into broad groups representing similar job tasks and exposures of interest, based on job title, job duties, company, type of product or service provided, and SIC and SOC coding. A variable was created for each occupational group that represented having ever worked in that occupation for at least six months (referred to as "ever worked" in this paper). Duration of each job was summed for each person across all jobs included within each occupational group. Variables were created that indicated 5- and 10-year durations of working in each occupational group. Latency of work in an occupational group ($\leq$10 years, $>$10 years) was calculated for each subject for each occupational group as the time between the earliest start date of any job in that occupational group until the interview date. Seven subjects with incomplete occupational histories were excluded from all analyses of occupation.

Statistical analyses

Occupational groups with a frequency of five subjects or greater for having ever worked in that occupation were included in all analyses and are shown in the tables. We used unconditional logistic regression to compute odds ratios (OR) and 95% confidence limits (CL), estimating rate ratios for the effect of having ever worked in that occupational group on glioma incidence. The referent population for each analysis comprised those subjects

who had never worked in that occupational group. We also computed relative confidence limit widths, defined as the upper confidence limit divided by the lower confidence limit, as a tool for evaluating precision of estimates [8]. In the context of evaluating multiple occupational groups in a case–control study, many of which were sparsely represented in the study population, CL widths of 10 or less were considered to indicate moderate precision. All effect estimates for occupational groups were adjusted for the study matching factors, coded as indicator variables. Further adjustment for education was conducted to assess possible confounding by this factor, coded as indicator variables (less than high school graduate; high school graduate with or without some college; college graduate or more). We also calculated odds ratios for 5- and 10-year durations, and greater than 10-year latency in an occupational group. In addition, we conducted analyses restricted to non-proxy respondents to assess the influence of reporting bias on the results we observed, analyses stratified by sex to explore differences in associations between men and women, and analyses stratified by tumor grade (low-grade *versus* high-grade) to explore whether associations differed by degree of malignancy.

Where associations were observed in our study among occupational groups and glioma incidence, data from certain job modules were used to further explore associations related to job-specific tasks and work practices. The job modules analyzed were chosen to closely match occupational groups for which associations were observed; however, the modules sometimes included slightly different groups of workers than the occupational groups. Job modules of interest for these analyses were those for butchers and meat cutters; computer operators; electricians and electronic equipment repairers; industrial machinery repairers; general farmers; janitors, housekeepers, and cleaners; production inspectors, checkers, and examiners; and welders, cutters, and burners. Data from the job modules of interest were analyzed by comparing the frequency of certain job tasks and work practices between glioma cases and controls, adjusting for the study matching factors, with persons who were not administered the job module as the referent.

Table 1. Characteristics of glioma cases and controls in study (frequency and percent)

Characteristic	Glioma cases[a] (n = 489)	Controls[b] (n = 799)
Sex		
Female	212 (43.4%)	436 (54.6%)
Male	277 (56.7%)	363 (45.4%)
Race		
White	444 (90.8%)	715 (89.5%)
Hispanic	26 (5.3%)	54 (6.8%)
Black	10 (2.0%)	19 (2.4%)
Other	9 (1.8%)	11 (1.4%)
Age (years)		
≤30	63 (12.9%)	113 (14.1%)
31–50	177 (36.2%)	320 (40.1%)
51–70	174 (35.6%)	270 (33.8%)
>70	75 (15.3%)	96 (12.0%)
Educational level		
Less than high school graduate	64 (13.1%)	105 (13.1%)
High school graduate with or without some college	252 (51.5%)	479 (60.0%)
College graduate or advanced degree	157 (32.1%)	194 (24.3%)
Missing data	16 (3.3%)	21 (2.6%)
Hospital site		
Phoenix, AZ	244 (49.9%)	405 (50.7%)
Boston, MA	153 (31.3%)	220 (27.5%)
Pittsburgh, PA	92 (18.8%)	174 (21.8%)
Proximity of residence to hospital (miles)		
0–5	125 (25.6%)	262 (32.8%)
5–15	155 (31.7%)	229 (28.7%)
15–30	116 (26.6%)	163 (20.4%)
30–50	42 (8.6%)	59 (7.4%)
≥50	51 (10.4%)	86 (10.8%)
Included in occupational analyses[c]		
No	5 (1.0%)	2 (0.2%)
Yes	484 (99.0%)	797 (99.8%)

[a] The glioma category includes neuroepitheliomatous tumors (ICD-O-2 codes 9380–9473 and 9490–9506 [3]). There were 236 glioblastomas, five gliosarcomas, 70 anaplastic astrocytomas, 34 other or unspecified astrocytomas, 46 oligodendrogliomas, nine anaplastic oligodendrogliomas, 30 mixed gliomas, seven ependymomas, three anaplastic ependymomas, three subependymal gliomas, 18 gangliogliomas, four neurocytomas, five medulloblastomas, one primitive neuroectodermal tumor, two neuroblastomas, one astroblastoma, one neuroepithelioma, and 14 gliomas of unspecified type.

[b] Controls were matched to the total case group including glioma, meningioma, and acoustic neuroma.

[c] Subjects not included due to incomplete occupational history.

Results

Glioma cases and controls in the study were similar with respect to race and hospital site (Table 1). Differences in distributions for some characteristics between glioma cases and controls are due to having controls matched to the total case series of benign and malignant tumors in the full study. Cases were, on average, more highly educated than controls.

Frequencies and effect estimates for occupational groups are presented in Table 2. Several occupational groups were associated with increased glioma incidence for having ever worked in the occupation (judged by odds ratio ≥1.5, lower CL ≥0.8, and relative CL width ≤10), including butchers and meat cutters; computer

Table 2. Estimated effects of occupational groups on glioma incidence: odds ratios [OR] and 95% confidence limits (95% CL)[a]

Occupational group	Ever worked			Worked > 5 years total		
	Cases (n = 484)	Controls (n = 797)	OR (95% CL)	Cases (n = 484)	Controls (n = 797)	OR (95% CL)
Actors, dancers, and directors	2	3	1.2 (0.2, 7.7)	1	0	∞ (0.0, ∞)
Aircraft mechanics	10	12	1.1 (0.5, 2.7)	4	3	1.8 (0.4, 8.4)
Airplane pilots, and navigators	5	8	0.7 (0.2, 2.3)	2	4	0.7 (0.1, 3.7)
Animal caretakers	4	12	0.5 (0.2, 1.6)	1	3	0.5 (0.1, 5.2)
Artists	5	7	1.4 (0.4, 4.4)	2	5	0.7 (0.1, 3.8)
Assemblers and packers	21	40	0.8 (0.5, 1.3)	3	7	0.6 (0.2, 2.4)
Athletes and related occupations	5	3	2.2 (0.5, 9.6)	2	1	2.9 (0.3, 34.7)
Automotive body and related repairers	1	5	0.3 (0.03, 2.6)	0	1	0.0 (0.0, ∞)
Automotive body painters	2	4	0.8 (0.2, 4.7)	1	1	2.2 (0.1, 38.5)
Brickmasons and stone and tile setters	2	10	0.3 (0.1, 1.3)	0	4	0.0 (0.0, ∞)
Butchers and meat cutters	12	8	2.4 (1.0, 6.0)	5	3	2.6 (0.6, 11.2)
Carpenters	14	22	0.9 (0.4, 1.7)	7	10	0.9 (0.4, 2.5)
Chemical industry workers	2	4	0.8 (0.1, 4.2)	0	3	0.0 (0.0, ∞)
Chemists and chemical laboratory technicians	4	6	0.8 (0.2, 3.1)	3	3	1.0 (0.2, 5.3)
Child-care workers	9	41	0.4 (0.2, 0.9)	1	9	0.2 (0.02, 1.6)
Clergy	6	8	1.0 (0.4, 3.1)	5	5	1.3 (0.4, 4.5)
Clinical and biological laboratory scientists and technicians	6	12	0.9 (0.3 2.4)	2	5	0.6 (0.1, 3.2)
Computer programmers and analysts	21	17	2.0 (1.0, 3.8)	11	7	2.4 (0.9, 6.4)
Concrete workers	5	8	1.0 (0.3, 3.0)	1	4	0.3 (0.04, 3.1)
Construction laborers	2	16	0.2 (0.04, 0.8)	1	0	∞ (0.0, ∞)
Construction managers	5	13	0.5 (0.2, 1.5)	2	9	0.3 (0.1, 1.3)
Construction workers	7	13	0.8 (0.3, 2.2)	3	6	0.7 (0.2, 2.8)
Cooks and kitchen workers	77	149	0.9 (0.6, 1.2)	12	25	0.9 (0.4, 1.8)
Counselors, social workers, and psychologists	14	30	0.8 (0.4, 1.5)	9	12	1.2 (0.5, 3.1)
Dentists and dental assistants	3	10	0.5 (0.1, 1.8)	3	3	1.4 (0.3, 7.4)
Designers and decorators	10	4	4.7 (1.4, 15.2)	2	2	1.7 (0.2, 12.7)
Drafting occupations	8	7	1.5 (0.5, 4.3)	6	1	7.8 (0.9, 65.6)
Drivers (cars and light trucks)	20	30	0.9 (0.5, 1.7)	3	8	0.6 (0.2, 2.3)
Dry-cleaner workers	6	14	0.8 (0.3, 2.2)	0	3	0.0 (0.0, ∞)
Drywall and plaster workers	2	5	0.6 (0.1, 3.0)	1	3	0.5 (0.05, 4.5)
Editors, reporters, and writers	10	16	1.1 (0.5, 2.5)	5	6	1.2 (0.4, 4.1)
Electrical engineers	11	9	1.6 (0.6, 3.9)	5	8	0.8 (0.2, 2.4)
Electrical installers	2	6	0.4 (0.1, 1.9)	0	2	0.0 (0.0, ∞)
Electrical technicians, assemblers, and repairers	23	32	1.0 (0.6, 1.7)	7	13	0.7 (0.3, 1.9)
Electricians	14	11	1.8 (0.8, 4.1)	8	5	2.3 (0.7, 7.2)
Engineering technicians	6	15	0.6 (0.2, 1.6)	1	6	0.2 (0.02, 1.7)
Engineers (NEC)	20	17	1.5 (0.8, 3.0)	13	10	1.7 (0.7, 4.0)
Equipment and parts cleaners	3	9	0.5 (0.1, 1.7)	0	0	ne
Exterminators	3	2	1.9 (0.3, 12.0)	2	0	∞ (0.0, ∞)
Fabricators (miscellaneous)	9	13	1.1 (0.5, 2.6)	3	1	4.4 (0.5, 42.9)
Firefighting occupations	2	7	0.3 (0.1, 1.7)	0	4	0.0 (0.0, ∞)
Food industry workers	7	11	1.1 (0.4, 2.8)	0	2	0.0 (0.0, ∞)
Forklift/crane operators	8	13	0.9 (0.4, 2.1)	3	5	0.8 (0.2, 3.4)
Gas station attendants	14	38	0.5 (0.3, 0.9)	3	5	0.8 (0.2, 3.6)
General farmers and farmworkers	29	18	2.5 (1.4, 4.7)	10	5	3.0 (1.0, 9.1)
General maintenance and handymen	14	13	1.4 (0.6, 3.0)	5	6	1.1 (0.3, 3.7)
Glaziers and glass workers	5	2	3.4 (0.7, 18.1)	2	0	∞ (0.0, ∞)
Gluers	3	6	0.8 (0.2, 3.2)	0	0	ne
Groundskeepers, landscapers and gardeners	13	21	0.9 (0.4, 1.8)	2	2	1.5 (0.2, 10.8)
Hairdressers, barbers, and cosmetologists	7	16	0.9 (0.3, 2.1)	3	5	1.1 (0.3, 4.8)
Health-care management and administration	4	10	0.8 (0.2, 2.5)	3	5	1.2 (0.3, 5.1)
Health services occupations (NEC)	3	13	0.4 (0.1, 1.4)	0	7	0.0 (0.0, ∞)
Health technicians (NEC)	5	15	0.7 (0.2, 1.9)	0	6	0.0 (0.0, ∞)
Heavy equipment operators	2	11	0.3 (0.1, 1.1)	1	5	0.3 (0.04, 2.8)
Inspectors, checkers, examiners, graders, and testers	23	24	1.5 (0.8, 2.7)	10	8	2.0 (0.8, 5.2)

Table 2. (Continued)

Occupational group	Ever worked			Worked > 5 years total		
	Cases (n = 484)	Controls (n = 797)	OR (95% CL)	Cases (n = 484)	Controls (n = 797)	OR (95% CL)
Investigators, examiners, adjusters, and appraisers	13	14	1.7 (0.8, 3.7)	6	5	1.9 (0.6, 6.4)
Janitors and custodians	14	26	0.8 (0.4, 1.6)	3	4	1.2 (0.3, 5.5)
Laborers (NEC)	23	38	0.8 (0.5, 1.4)	7	6	1.3 (0.4, 4.1)
Laundry workers	6	7	1.7 (0.6, 5.4)	0	2	0.0 (0.0, ∞)
Librarians and library clerks	3	17	0.3 (0.1, 1.1)	1	4	0.3 (0.04, 3.0)
Livestock, dairy, poultry farmers and farmworkers	6	11	0.7 (0.3, 2.1)	2	2	1.2 (0.2, 8.9)
Loggers and lumber workers	3	3	1.2 (0.2, 5.9)	2	0	∞ (0.0, ∞)
Machine operators and tenders (NEC)	11	16	1.0 (0.4, 2.2)	6	5	1.8 (0.5, 6.1)
Maids, housekeepers, and cleaners	17	29	1.2 (0.7, 2.3)	10	9	2.2 (0.8, 5.5)
Mail carriers and messengers	9	17	0.7 (0.3, 1.6)	3	4	0.9 (0.2, 4.2)
Mail clerks	6	15	0.6 (0.2, 1.5)	0	3	0.0 (0.0, ∞)
Managers (NEC)	124	186	1.1 (0.8, 1.4)	78	122	0.9 (0.7, 1.3)
Managers, food service and lodging	11	21	0.9 (0.4, 1.8)	4	6	1.2 (0.3, 4.4)
Managers, mechanics and repairers	2	6	0.5 (0.1, 2.4)	0	0	ne
Marketing, advertising, and public relations	25	46	0.8 (0.5, 1.4)	11	23	0.7 (0.3, 1.5)
Mechanics and repairers (NEC)	30	37	1.2 (0.7, 1.9)	12	11	1.5 (0.6, 3.5)
Metal processing occupations	13	15	1.2 (0.5, 2.6)	5	6	1.1 (0.3, 3.9)
Metalworking occupations	19	30	0.8 (0.5, 1.5)	7	11	1.0 (0.4, 2.6)
Military occupations	34	35	1.2 (0.7, 2.0)	1	7	0.2 (0.02, 1.6)
Mining workers	2	3	0.9 (0.1, 5.3)	0	1	0.0 (0.0, ∞)
Musicians and composers	4	11	0.6 (0.2, 1.8)	3	6	0.9 (0.2, 3.5)
Nurses, registered and licensed practical	16	41	0.8 (0.4, 1.5)	12	28	0.9 (0.4, 1.8)
Nursing aides, orderlies, and attendants	26	59	0.9 (0.5, 1.4)	7	15	0.9 (0.4, 2.4)
Office clerks (NEC)	147	253	1.1 (0.8, 1.5)	66	122	0.9 (0.7, 1.4)
Office machine operators	1	6	0.3 (0.03, 2.3)	0	2	0.0 (0.0, ∞)
Office professionals (NEC)	39	64	1.0 (0.7, 1.5)	18	27	1.1 (0.6, 2.0)
Officials and administrators, public programs and education	10	16	1.0 (0.5, 2.3)	5	10	0.8 (0.3, 2.4)
Painters	12	24	0.7 (0.3, 1.4)	2	9	0.3 (0.1, 1.5)
Paper industry workers	2	3	0.9 (0.2, 5.8)	1	1	1.5 (0.1, 24.4)
Personal service occupations (NEC)	18	26	1.2 (0.7, 2.3)	4	2	3.1 (0.6, 17.3)
Pharmacists	2	5	0.7 (0.1, 3.7)	2	4	0.8 (0.1, 4.4)
Photographers and photo processing	4	8	1.0 (0.3, 3.3)	2	5	0.7 (0.1, 3.9)
Physicians and physician assistants	9	5	2.4 (0.8, 7.2)	7	5	1.9 (0.6, 6.1)
Plastics workers	3	7	0.7 (0.2, 2.7)	1	0	∞ (0.0, ∞)
Plumbers, pipefitters, and steamfitters	3	12	0.3 (0.1, 1.2)	3	5	0.8 (0.2, 3.2)
Police, detectives, and guards	19	33	0.8 (0.4, 1.4)	7	15	0.6 (0.2, 1.5)
Power plant and boiler operators	1	8	0.2 (0.02, 1.2)	0	2	0.0 (0.0, ∞)
Printers	5	13	0.6 (0.2, 1.7)	2	3	1.0 (0.2, 6.3)
Production managers and supervisors (industry)	10	10	1.3 (0.5, 3.2)	3	3	1.2 (0.2, 6.5)
Property managers	2	6	0.5 (0.1, 2.6)	0	2	0.0 (0.0, ∞)
Purchasing agents and buyers	7	14	0.8 (0.3, 2.1)	3	5	0.8 (0.2, 3.6)
Radio broadcasters, dispatchers, and air traffic controllers	23	33	1.0 (0.5, 1.7)	2	12	0.2 (0.05, 1.0)
Radiologic technicians	2	5	0.8 (0.2, 4.2)	0	2	0.0 (0.0, ∞)
Railroad occupations	6	7	1.1 (0.4, 3.3)	0	4	0.0 (0.0, ∞)
Recreation workers and physical education teachers	20	24	1.5 (0.8, 2.8)	5	10	0.8 (0.3, 2.4)
Researchers and research assistants (except laboratory)	5	8	1.0 (0.3, 3.1)	2	5	0.7 (0.1, 3.7)
Roofers	4	7	0.9 (0.3, 3.0)	2	1	3.0 (0.3, 33.5)
Sailors and fishermen	2	8	0.3 (0.1, 1.2)	0	5	0.0 (0.0, ∞)
Sales clerks and cashiers	123	217	1.0 (0.8, 1.3)	27	48	1.0 (0.6, 1.6)
Sales representatives	47	66	1.2 (0.8, 1.7)	22	25	1.5 (0.8, 2.7)
Seamstresses and tailors	6	9	1.1 (0.4, 3.2)	1	3	0.6 (0.1, 5.7)
Shoemakers and leather workers	7	4	2.4 (0.7, 8.6)	2	2	1.0 (0.1, 7.4)
Stock handlers, shippers, and receivers	51	94	0.7 (0.5, 1.1)	9	19	0.7 (0.3, 1.5)
Store managers	18	20	1.6 (0.8, 3.1)	6	4	2.1 (0.6, 7.5)

Table 2. (Continued)

Occupational group	Ever worked			Worked > 5 years total		
	Cases (n = 484)	Controls (n = 797)	OR (95% CL)	Cases (n = 484)	Controls (n = 797)	OR (95% CL)
Teachers and instructors	47	72	1.1 (0.8, 1.7)	28	32	1.5 (0.9, 2.6)
Telephone and switchboard operators	12	30	0.8 (0.4, 1.5)	3	6	0.9 (0.2, 4.0)
Textile industry workers	5	14	0.6 (0.2, 1.7)	4	7	1.0 (0.3, 3.7)
Truck drivers (heavy)	31	63	0.7 (0.4, 1.1)	13	26	0.7 (0.3, 1.3)
Vehicle mechanics and repairers	8	22	0.5 (0.2, 1.2)	5	12	0.6 (0.2, 1.7)
Waiters and bartenders	56	115	0.9 (0.6, 1.3)	16	34	0.8 (0.4, 1.5)
Welders and cutters	10	18	0.8 (0.3, 1.7)	6	4	2.1 (0.6, 7.5)
Woodworkers	3	7	0.6 (0.2, 2.5)	1	4	0.4 (0.04, 3.6)

NEC = not elsewhere classified; ne = not estimated.
[a] All estimates are adjusted for the matching factors including age, sex, hospital, distance of residence from hospital.

programmers and analysts; electricians; engineers (NEC); general farmers and farmworkers; inspectors, checkers, examiners, graders, and testers; investigators, examiners, adjusters, and appraisers; physicians and physician assistants; recreation workers and physical education teachers; and store managers. There were statistically significant decreased odds ratios for associations between glioma incidence and occupations as child-care workers or construction laborers. Most of these associations persisted for those subjects who had worked longer than five years in the occupation and for those with at least a 10-year latency since starting work in the occupation (results for latency not shown). These occupational groups were associated with both high- and low-grade glioma, and were associated in analyses restricted to non-proxy respondents (results not shown). Some of the associations were attenuated by adjustment for education, including physicians and physician assistants (OR = 2.0; 95% CL: 0.6, 6.0) and recreation workers and physical education teachers (OR = 1.3; 95% CL: 0.7, 2.4), but education was not an important confounder for most occupational groups. Some associations with occupational groups were stronger for those having worked longer than five years, compared to having ever worked in the occupation (>20% increase or decrease in the odds ratio), including electricians, inspectors, etc., store managers, and child-care workers (Table 2). Although having ever worked as maids, housekeepers, and cleaners was not associated with glioma, there was an association for working in the occupation longer than five years.

Other notable results from the analysis of having ever worked in the occupation were rather imprecise positive associations with glioma incidence for athletes and related occupations, designers and decorators, glaziers and glassworkers, and shoemakers and leather workers, and an inverse association for construction laborers (Table 2). These associations generally did not persist in analyses of greater than five years duration in the occupation, although small numbers limited interpretation. There were also increased, though imprecise, positive associations for having worked longer than five years in drafting occupations, personal service occupations (NEC), and as welders and cutters.

Most associations were present among both men and women, but there were several clear differences (selected results shown in Table 3). Positive associations of glioma incidence with occupation as computer programmers and analysts, inspectors, etc., investigators, etc., and store managers occurred solely among men. Similarly, an imprecise overall association of glioma incidence with occupation as shoemakers and leather workers appeared to be driven by an excess of cases among men only.

Analysis of job-specific tasks and work practices resulted in some suggestive associations (Table 4), although these estimates were rather imprecise due to small numbers. For butchers and meat cutters administered the job module, cumulative meat-handling hours was not associated with glioma in an exposure–response fashion. There was some indication, however, that subjects who did not wear gloves when handling meat, and those who had cuts on their hands at least once per month, had higher glioma incidence than butchers not reporting those factors. For computer operators, neither years in the job nor cumulative number of hours working with a computer was associated with glioma incidence in an exposure–response fashion, in contrast with our results for the occupational group. For electricians and electronic equipment repairers, increased glioma incidence was associated with construction wiring and working for a utility company, but not for wiring in existing buildings or for repairing electronic equipment. For general farmers, increased glioma

Table 3. Differences between men and women in associations of occupational groups with glioma incidence (odds ratios (OR) and 95% confidence limits (95% CL)[a]

Occupational group	Men			Women		
	Cases (n = 273)	Controls (n = 363)	OR (95% CL)	Cases (n = 211)	Controls (n = 434)	OR (95% CL)
Computer programmers						
Ever/never	17	9	2.5 (1.0, 5.7)	4	8	1.1 (0.3, 3.8)
>5 years	11	4	3.8 (1.2, 12.3)	0	3	0.0 (0.0, ∞)
>10 years	7	2	4.5 (0.9, 22.7)	0	2	0.0 (0.0, ∞)
Inspectors, checkers, examiners, graders, testers						
Ever/never	19	14	2.0 (1.0, 4.2)	4	10	0.6 (0.2, 2.1)
>5 years	10	5	3.5 (1.1, 10.8)	0	3	0.0 (0.0, ∞)
>10 years	4	3	2.2 (0.5, 10.3)	0	2	0.0 (0.0, ∞)
Investigators, examiners, adjusters, appraisers						
Ever/never	7	2	5.3 (1.0, 27.0)	6	12	1.0 (0.4, 2.8)
>5 years	4	2	3.1 (0.5, 18.5)	2	3	1.1 (0.2, 6.8)
>10 years	3	1	4.8 (0.5, 50.6)	1	2	0.7 (0.1, 8.3)
Shoemakers and leather workers						
Ever/never	5	0	∞ (0.0, ∞)	2	4	0.9 (0.2, 5.2)
>5 years	2	0	∞ (0.0, ∞)	0	2	0.0 (0.0, ∞)
Store managers						
Ever/never	11	4	3.8 (1.2, 12.5)	7	16	0.9 (0.4, 2.3)
>5 years	5	0	∞ (0.0, ∞)	1	4	0.4 (0.04, 3.8)
>10 years	4	0	∞ (0.0, ∞)	1	0	∞ (0.0, ∞)

[a] All estimates are adjusted for the matching factors including age, hospital, distance of residence from hospital.

incidence was associated with raising farm animals but not with crop farming; we were unable to distinguish the risk associated with specific types of crops and animals because the farmers reported multiple products. Farmers who spent time in an animal confinement building or egg-laying house were at increased risk of glioma, whereas farmers who spent no time in such structures were not. Although pesticide use on the farm was not associated with increased glioma incidence, there was some suggestion that farmers who personally applied pesticides to crops had higher risks of glioma. There were no notable associations for the other modules we examined that would indicate high-risk tasks or work practices.

Discussion

One advantage of studying occupational title, as opposed to self-reported occupational exposures, is that studies of validity and reliability show that people can report their occupational history fairly accurately, with levels of raw agreement for employer, job classification, person-years in a job, and start and termination dates generally in the range of 70–90% [9]. In contrast, self-reporting of occupational exposures has consistently lower validity and reliability [9]. The obvious disadvantage of using occupational title as a measure of exposure is that it can act only as a surrogate for causal agents in the workplace. Our study corroborates several associations found in prior studies, including the positive findings for butchers and meat cutters, electricians, engineers (NEC), general farmers, and physicians and physician assistants. We also found positive associations with the occupational groups of inspectors, etc. and investigators, etc., and store managers, and an inverse association with occupation as a child-care worker. Analyses of information from the job-specific modules provided clues about possible high-risk tasks and work practices, such as not wearing gloves for butchers, and raising livestock or personally applying pesticides for farmers.

One of the more consistent findings in the relevant literature is that of increased brain tumor incidence among farmers and related workers [10]. This association has been observed in cohort [11–15] and case–control studies [16–22] conducted in different parts of the world, and was supported by a recent meta-analysis (OR = 1.3; 95% CL: 1.1, 1.6) [23]. Our study, although conducted in primarily urban metropolitan areas of the United States, nevertheless provides further support for this association. Previous studies have observed

Table 4. Estimated effects of job tasks and exposures reported in job modules on glioma incidence: odds ratios (OR) and 95% confidence limits (95% CL)[a,b]

Job module	Cases (n = 484)	Controls (n = 797)	OR (95% CL)
Butchers and meat cutters	8	5	2.4 (0.7, 7.4)
Years in occupation			
≤5 years	4	2	2.0 (0.4, 9.5)
>5 years	4	3	2.8 (0.5, 15.8)
Cumulative meat-handling hours			
Cumulative hours ≤median	4	1	5.5 (0.6, 50.3)
Cumulative hours >median	4	3	2.0 (0.4, 9.5)
Cuts on hands at least once per month			
No	1	2	1.0 (0.1, 10.8)
Yes	5	3	2.4 (0.6, 10.3)
Wore gloves when handling meat			
No	6	2	4.5 (0.9, 23.1)
Yes	2	2	1.6 (0.2, 11.6)
Computer operators	13	13	1.7 (0.8, 3.8)
Years in occupation			
≤5 years	5	6	1.4 (0.4, 4.7)
>5 years	3	4	1.3 (0.3, 6.0)
Cumulative computer hours			
Cumulative hours ≤median	7	5	2.3 (0.7, 7.5)
Cumulative hours >median	5	7	1.2 (0.4, 4.0)
Electricians and electronic equipment repairers	21	17	1.7 (0.9, 3.2)
Years in occupation			
≤5 years	10	4	3.3 (1.0, 10.6)
>5 years	7	9	0.9 (0.3, 2.6)
Types of tasks			
Installed wiring in buildings under construction	5	3	2.6 (0.6, 11.0)
Repaired, maintained, or installed wiring in existing buildings	5	6	1.1 (0.3, 3.6)
Worked for utility company	3	2	2.7 (0.4, 16.6)
Repaired electronic equipment	14	14	1.3 (0.6, 2.8)
General farmers	14	13	1.5 (0.7, 3.4)
Years in occupation			
≤5 years	5	5	1.6 (0.4, 5.6)
>5 years	7	4	2.5 (0.7, 8.8)
Farmed crops			
No	4	3	1.9 (0.4, 9.1)
Yes	10	10	1.4 (0.6, 3.5)
Raised farm animals			
No	1	2	0.7 (0.1, 7.7)
Yes	13	11	1.7 (0.7, 3.9)
Farmed crops and raised farm animals, in same model			
Farmed crops	10	10	0.7 (0.1, 3.4)
Raised farm animals	13	11	2.3 (0.5, 10.2)
Spent time in animal confinement building or egg-laying house			
No	8	11	1.0 (0.4, 2.5)
Yes	6	2	4.9 (1.0, 25.3)
Pesticides used on the farm			
No	6	3	2.7 (0.7, 11.0)
Yes	8	8	1.4 (0.5, 4.0)
Personally applied herbicides to crops			
No	8	9	1.4 (0.5, 3.6)
Yes	5	1	5.7 (0.7, 50.4)
Personally applied insecticides to crops			
No	10	8	1.9 (0.7, 4.9)
Yes	3	1	3.3 (0.3, 32.9)
Personally applied insecticides to animals			
No	8	6	2.0 (0.7, 6.0)
Yes	5	3	2.2 (0.5, 9.6)

[a] All estimates are adjusted for matching factors including age, sex, hospital, distance of residence from hospital.
[b] Reference group for each job module includes all subjects not administered that module.

increased glioma incidence associated with general farming as well as specifically for livestock, dairy, and poultry farming [18, 20]. Positive associations in our study were observed only for general farmers and farmworkers, but this does not preclude the possibility of risk associated with livestock, dairy, or poultry farming. Almost every general farmer and farmworker who worked in this occupational group longer than five years reported tending farm animals (11 out of 15 total) in addition to crops, indicating common exposures across the two groups. Our analysis of the job module for farmers (which included both crop- and animal-farmers) indicated that raising livestock was associated with increased glioma incidence, whereas raising crops, *per se*, was not. Further indication of an association between exposure to farm animals and glioma was the nearly five-fold increased risk associated with work in animal confinement buildings or egg-laying houses. These results could indicate an etiology attributable to infectious agents, dusts, or insecticides applied to animals. While use of pesticides on the farm was not associated with glioma, personal application of pesticides to crops or animals was associated with increased glioma incidence, possibly indicating the importance of information on work practices in evaluating risk.

There has been much interest and debate on the potential relationship of extremely low-frequency electric and/or magnetic fields (EMF) with brain tumors, and several studies have reported positive associations of brain tumors with highly exposed occupations or for estimated high levels of occupational EMF exposures [17, 18, 20, 24–35]. A meta-analysis reported a weak positive association, based on rather consistently elevated, yet heterogeneous, estimates across different studies [36]. Our results are somewhat compatible with the hypothesis of EMF as a risk factor for brain tumors. Occupations for which we observed elevated odds ratios, such as electricians and welders and cutters (for >5 years duration), generally receive among the highest levels of EMF exposure of any jobs [37, 38]. We also observed an increased risk for computer programmers and analysts, as found in some previous studies [20, 39]. There was no exposure–response relationship with the number of hours spent working at a computer; however, the number of hours spent working at a computer was poorly correlated with EMF exposure in a validation study [40]. Other occupations or tasks with potential EMF exposure that were associated with glioma in our study include engineers (NEC), and electricians or electronic equipment repairers working in construction wiring or for a utility company. In these occupations there are exposures other than EMF, as well as highly varied tasks. For example, the tasks of electricians in our study included cleaning and degreasing metal parts, welding, and soldering. Assessment of EMF as a possible risk factor awaits individual exposure assessment for EMF and other potentially confounding exposures.

Several studies have reported positive associations between brain tumor incidence and occupations in the medical field, including physicians, nurses, dentists and dental assistants, and veterinarians [13, 14, 22, 32, 33, 41–48]. Data from our study were inconsistent in this regard. Although the effect estimate for physicians and physician assistants was elevated, there was no evidence of increased risk for those working as nurses, nursing aides, or as dentists and dental assistants. Once again, there is a potential etiologic pathway through exposure to infectious agents; however, many such exposures would be common across the medical occupations, and the fact that no association was seen in the other occupations detracts from this hypothesis. Education and income level are positively associated with glioma incidence [49], possibly leading to spurious results for occupations requiring higher education, such as physicians. Although education did confound the result for physicians and physician assistants, it did not completely account for the association. Another possibility is increased detection of glioma among groups with higher education or income, creating a selection bias for cases; such a ''diagnostic bias'' has been previously observed in groups with more complete medical evaluation than the general population [50]. In our study the risk of glioma was elevated among physicians and physician assistants for both high- and low-grade tumors, arguing against such a diagnostic bias.

Other occupations for which we observed increased glioma incidence have been associated with glioma in some, but not all, previous studies. Positive associations have been previously reported for butchers or meat cutters [51], although no such association was observed in a cohort of meat-packing workers [52] or in a large record-linkage study from Sweden [53]. In our study the work practices for butchers associated with increased glioma incidence included not wearing gloves and frequently having cuts on hands, possibly indicating an etiologic mechanism involving an infectious agent. Several previous studies also corroborate our findings of increased glioma incidence associated with occupation as aircraft or airfield workers [54], draftspersons [45], designers [45], maids, housekeepers, or cleaners [17, 39], mechanics or repairers [16, 17, 45], shoemakers and leather workers [20], various sales occupations [17], and glass products workers [14, 33]. Our finding of reduced glioma incidence among child-care workers is of interest

in light of reports of reduced risk associated with a history of infections, allergies, or hyperstimulated immune system [55–57].

A number of other occupational groups previously associated with brain tumors did not emerge in our study as high-risk groups, including painters [13, 32, 42, 48], textile workers [13, 17, 20, 21, 33], sheet and structural metal workers [17, 20, 45, 58], and firefighters [16], although the numbers of subjects in some jobs were small [59, 60]. For several occupations previously linked with glioma, there were too few subjects employed in these occupations in our study population to assess effects, including petroleum industry workers [31, 51, 61–63], rubber workers [13, 17, 20, 26, 32, 64, 65], chemical industry workers [62], embalmers and pathologists [66–70], and forestry and logging workers [39, 58, 59].

Some occupations were associated with glioma incidence among men only, such as computer programmers and analysts, and inspectors, etc. Differences in results may be due to imprecision resulting from smaller numbers of women employed in the occupations, dissimilarities in the types of jobs held by men and women within an occupational group [71], or true biological differences in effect by sex.

In this initial report from one of the larger multicenter case–control studies of glioma to date, we provide information on occupational groups as well as specific tasks and work practices within jobs. This examination of occupation is a first step in our analysis in which occupation was a primary focus and in which an industrial hygienist was integrally involved in the design and data collection. In addition to collecting a complete occupational history, employment in certain jobs (*e.g.* farmers, butchers, etc.) prompted administration of the job module questionnaires [4], from which detailed information on tasks and exposures was collected. The cost of this wealth of data comes in the numerous hours required for industrial hygienists to review the information in order to code specific exposures across different jobs. Although we evaluated a large number of occupational groups, tasks, and work practices in this analysis, and some of the observed associations may be due to chance, results will nevertheless help to direct the exposure-specific analyses. A series of detailed examinations of occupational exposures and brain tumor incidence in this study will include chlorinated solvents, EMF, pesticides, lead, and other exposures. These future analyses should, in turn, give further insight to the associations with occupational groups, for both the positive and non-associations we observed. This tiered approach recognizes that, while examination of occupational group can be informative, specific knowledge of carcinogenic exposures within occupations can lead to protective measures.

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